ISSN 2319 – 7757 EISSN 2319 – 7765

Indian Journal of Engineering

Behaviour of high performance concrete in exterior beam-column joint – a general review

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Received 13 February; accepted 25 March; published online 01 April; printed 16 April 2013

ABSTRACT

This paper formulates the feasibility of using High Performance Concrete as a means to eliminate the need for confinement (transverse) reinforcement and the associated construction problems in beam-column connections subjected to external loading. Beam-column joint is a typical lateral and vertical load resisting member in reinforced concrete structures which are particularly vulnerable to failures during earthquake. For achieving the strong and durable concrete, High Performance Concrete is the best suited when compared to ordinary concrete. In addition to the ingredients of High Performance Concrete with silica fume, glass fibres were introduced for reducing shrinkage cracks and to further increase the tensile property. This general review has given the platform for the research work based on influence of High Performance Concrete in Exterior beam-column joint. Finally, conclusion has been made in this paper for the future line of work.

Keywords: High Performance Concrete, Exterior Beam-Column Joint, Glass Fibre, Silica Fume.

1. INTRODUCTION

In Reinforced Concrete buildings, portion of columns that are common to beams at their intersections are called Beam-Column joint. Their constituent materials have limited strength; the joints have limited force carrying capacity. When forces larger than these are applied during Earthquake, joints are severely damaged. There are three types of joints can be identified viz. Interior joint, Exterior joint, Corner joint. While comparing the three types of joints, Exterior Beam-Column joint will be the most affected under any external loading. In Exterior joints where beams terminate at columns, longitudinal beam bars need to be anchored into the column to ensure proper gripping of bar in joint. Recent earthquakes in different parts of the world have revealed again the importance of design of reinforced concrete structures with high ductility. Strength and ductility of structures depend mainly on proper detailing of the reinforcement in beam-column joints. The flow of forces within a beam-column joint may be interrupted if the shear strength of the joint is not adequately provided. Under Seismic excitations, the beam-column joint region subjected to horizontal and vertical shear forces whose magnitude are many times higher than those within the adjacent beams and columns. However, fibre concrete can sustain a portion of its resistance following cracking to resist more cycles of loading (Ganesan et al., 2007). Due to the congestion of reinforcement, casting of beam-column joint will be difficult and will lead to honeycombing in concrete (Kumar et al., 1991).Damages in reinforced concrete structures are mainly attributed to shear force due to the inadequate detailing of reinforcement and lack of transverse steel and confinement of concrete in structural elements. Murthy et al., (2003) have tested the exterior beam-column joint subject to static cyclic loading by changing the anchorage detailing of beam reinforcement and shear reinforcement. The authors reported that the practical joint detailing using hairpin-type reinforcement is a competitive alternative to closed ties in the joint region.

Bindhu and Jaya (2008) deals with the non-conventional reinforcement detailing in the beam-column joint by providing inclined bars on the two faces of the joint core, which leads to reduction in compaction and construction difficulties due to congestion of reinforcement in the joint region. Bindhu and Jaya (2010) reported that confinement of core concrete without congestion of reinforcement in joints by providing additional cross bracing bars provided on two faces of joint as confining reinforcements. Perumal and Thanukumari (2010) reported that conventional concrete loses its tensile resistance after formation of cracks, fibre concrete can sustain a portion of its resistance following cracking to resist more cycles of loading. Malathy et al., (2007) investigated the effect of glass fibre on restrained shrinkage cracking in concrete especially High Performance Concrete because plastic shrinkage and drying shrinkage were the shortcomings of High Performance Concrete with those additives like silica fume, metakoaline, fly ash and superplasticizer.

2. EXPERIMENTAL PROGRAM

2.1. Details of Specimens

Ganesan et al., (2007) investigated ten exterior beam-column joints were cast and tested under flexural cyclic loading. The beams were 200mm deep by 150mm wide and columns were 200mm deep by 150mm wide with 800mm long beams measured from column face with an inter-storey height of 1000mm. The column was reinforced with four 12mm diameter bars and beam was provided with two 12mm bars at the top and bottom. High Yield Strength Deformed bars of 6mm diameter bars

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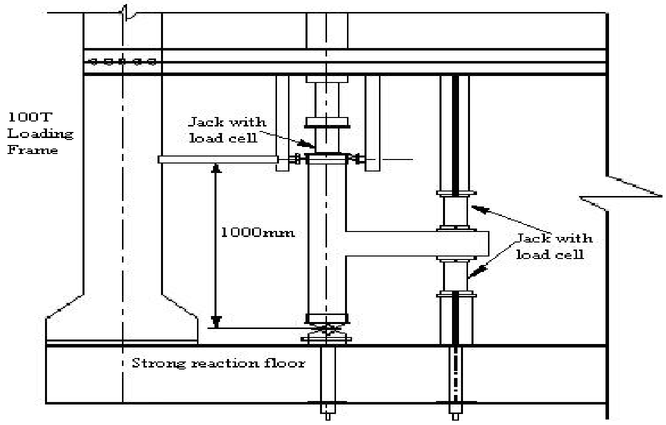

Figure 1
Schematic diagram of test set-up

were used for transverse ties in the column and stirrups in the beams. High Performance Concrete of M60 mix was prepared with 10% replacement of cement by silica fume, 20% fly ash and four different volume fractions of fibre (crimped steel fibre with an aspect ratio of 66), viz., 0.25, 0.50, 0.75 and 1.00. A naphthalene-based superplasticizer was added to the mixes for getting required workability.

Bindhu and Jaya (2010) classified the exterior beam-column joint specimens into two groups with two numbers in each group. The group A specimens were cast with reinforcement detailing as per IS 456:2000 and using the detailing provisions in SP:34. The group B specimens were detailed as per IS 456:2000 with additional diagonal cross bracing reinforcement at the two faces of the joints for confinement of joint. The beams were 150mm deep by 100mm wide and columns were 150mm deep by 100mm wide. The units were one-third of full scale with 550mm long beams measured from column face with an inter-storey height of 1000mm. The column was reinforced with four 8mm diameter bars at corner, four 6mm diameter bars at intermediate between the corner bars and beam was provided with two 8mm and 6mm diameter bars each at the top and bottom. Concrete mix prepared for the beam-column joint specimens with the compressive strength of the cubes at 28 days was 44.22MPa. All the specimens were tested under axial load and cyclic loading at the end of the beam.

The experimental program included that the exterior beam-column joint specimens into two groups with two numbers in each group. The group A specimens were cast with reinforcement detailing as per IS 13920:1993. The group B specimens were detailed as per IS 13920:1993, but by replacing the stirrups at joint region by diagonal cross inclined reinforcement at the two faces of the joints for confinement of joint. The beams were 150mm deep by 100mm wide and columns were 150mm deep by 100mm wide. The units were one-third of full scale with 550mm long beams measured from column face with an inter-storey height of 1000mm. The column was reinforced with four 8mm diameter bars at corner, four 6mm diameter bars at intermediate between the corner bars and beam was provided with two 8mm and 6mm diameter bars each at the top and bottom. Concrete mix prepared for the beam-column joint specimens with the compressive strength of the cubes at 28 days was 44.22MPa. All the specimens were tested under constant axial load with cyclic loading at the end of the beam, Bindhu and Jaya (2008). Perumal and Thanukumari (2010) carried out to investigate the behaviour of exterior beam-column joint made of hybrid fibre (combinations of steel and polypropylene fibres) reinforced concrete. There were five sets of High Strength Concrete specimens representing an exterior beam-column joint subjected to reversed cyclic loading were tested under displacement controlled loading. The first specimen was cast without seismic detailing as per IS 456-2000. The second specimen was cast as per seismic detailing code of IS 13920-1993. Hybrid fibre combination was mixed in the range of 1.5% of steel fibre and 0 to 0.4% of polypropylene fibre with an increment of 0.2%.

2.2. Testing of Specimens

Exterior beam-column joint specimens were tested in a Universal Testing Machine of 294.3 kN capacity. The constant load of 15.7 kN, which is about 20% of the axial capacity of the column, was applied to the columns for holding the specimens in position. A hydraulic jack of 4.9 kN capacity was used to apply load at the beam. The increment of loading was taken as 0.05 kN. The beam was loaded up to the first increment, then unloaded and reloaded to the next increment of load, and this pattern of loading was continued for each increment. Three numbers of Liner Variable Differential Transducers were used to measure the deformations and later strains at different locations, Ganesan et al., (2007).

Bindhu and Jaya (2008), Bindhu and Jaya (2010) tested the beam-column joint assemblages were subject to axial load and reverse cyclic loading. The schematic diagram of test set-up as shown in Fig.1. A constant column axial load was applied by means of a 392.4 kN hydraulic jack mounted vertically to the loading frame for simulating the gravity load on the column. Axial load for the first series specimens was 15.92 kN and for the second series was 53.06 kN. One end of the column was given an external hinge support, which was fastened to the strong reaction floor, and the other end was laterally restrained by a roller support. Reverse cyclic loading was applied by two 200 kN hydraulic jacks, one fixed to the loading frame at the top and other to the strong reaction floor. The test was load controlled and the specimen was subject to an increasing cyclic load up to failure. The load increment chosen was 1.962 kN. The specimens were instrumented with Linear Variable Differential Transformer to measure the deflection at loading point.

Perumal and Thanukumari (2010) tested exterior beam-column joint specimens under reversed cyclic loading in the loading frame. The reversed cyclic loading was applied by using one screw jack for giving downward displacement and one hydraulic jack for giving upward displacement at the end of the beam at a distance of 50mm from the beam end. The loading programme consisted of a simple history of reversed symmetric displacement amplitudes of 5mm, 10mm, 15mm, 30mm, 45mm.The test was done with displacement control and the specimens was subjected to an increasing reversed cyclic displacement up to failure.

3. RESULTS DISCUSSION

Ganesan et al., (2007) reported that, large number of closely spaced finer cracks appeared in the Steel Fibre Reinforced HPC beam-column joint specimens and the width of such cracks was smaller than the crack width in the HPC beam-column joint specimens and the ultimate load and corresponding deflection of specimens were found to increase as the fibre content increased. The first crack load of the HPC specimens with 1% fibre content was 11.28 kN, showed an increase of about 20% with HPC specimens without fibre and the ultimate load was 32.37kN, which was about 37% increase when compared to the HPC specimens. The deflection of peak load was 51kN which was about 75% increase when compared to the HPC specimens. The stiffness of the joint with fibres will not undergo much reduction when compared to that without fibres. And also concluded that, possible to reduce the congestion of steel reinforcement in the beam-column joint by replacing part of ties in the columns by steel fibres. Bindhu and Jaya (2008) observed that the specimens with diagonal confining bars, no cracks were noticed at the joint and the joint remained intact throughout the test. The experimental yield load and ultimate load obtained for the specimens with diagonal confining bars was 15.7kN and 18.64kN, which was about an increase of 33% and 17% respectively. The energy dissipation and ductility was improved in the specimens by the addition of diagonal confining bars at the joint. Finally concluded that, the specimens detailed as per IS 13920 with diagonal confining bars had improved ductility and energy absorption capacity than specimens detailed as per IS 13920-1993. The displacement ductility is increased considerably for the non-conventionally detailed specimens. Bindhu and Jaya (2010) observed the specimens same as the previous work but reinforcement was designed as per IS 456-2000. The experimental yield load and ultimate

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load obtained for the specimens with diagonal confining bars was 14.72kN and 19.62kN, which was about an increase of 7% and 26% respectively. Finally Concluded that, the specimens detailed as per IS 456 with diagonal confining bars had improved ductility and energy absorption capacity than specimens detailed as per IS 456-2000.

Perumal and Thanukumari (2010) observed that the specimens with hybrid fibre had the ultimate load of 37.6kN, which was about 77.5% higher than the specimens cast without fibre and 9.5% higher than the specimen cast by using steel fibre only with the ultimate load of 34.4kN. Finally concluded that, the hybrid fibre reinforced joints undergo large displacements without developing cracks when compared to SFRHPC and HPC joints. It was possible to reduce the congestion of steel reinforcement in beam-column joint by replacing part of ties in columns by steel and synthetic fibres and thereby reducing the cost. Malathy et al., (2007) observed that the slight increase in compressive strength of all concrete mixes was found with the addition of glass fibres. Silica fume concrete with mineral admixtures showed maximum crack width fibre volume fraction of 0.3% was required to control plastic shrinkage cracks in 10% silica fume concrete.

4. CONCLUSION

The main conclusions derived from this general review are as follows:

- This general review has given the guidelines for casting exterior beam-column joint with HPC mix with various replacements levels.
- The congestion of steel reinforcement in beam-column joint was reduced by replacing part of ties in columns by various types of fibres.
- The reinforcement detailed as per IS 456-2000 and IS 13920-1993 had been tested with and without diagonal cross bars in the joint region and achieved the better results.
- For reducing the plastic shrinkage cracks in concrete, HPC mixes with 10% silica fume and 0.3% glass fibre showed better results.
- In the future line of work, Exterior beam-column joint with diagonal cross bars in the joint and HPC mix with 10% silica fume, 0.3% glass fibre will be tested and behaviour of specimen with reinforcement detailing as per construction code of practice and ductile detailing has been studied.

REFERENCES

1. Bindhu KR, Jaya KP. Performance of Exterior Beam Column Joint with Cross-Inclined Bars under Seismic Loading. *Journal of Engineering and Applied Sciences*., 2008, 3(7), 597-597
2. Bindhu KR, Jaya KP. Strength and Behaviour of Exterior Beam-Column Joint with Diagonal Cross Bracing Bars. *Asian Journal of Civil Engineering (Building and Housing).*, 2010, 11(3), 397-410
3. Ganeshan N, Indira PV, Ruby Abraham. Steel Fibre Reinforced High Performance Concrete Beam-Column Joints Subjected to Cyclic Loading. *ISET Journal of Earthquake Engineering.*, 2007, 44(3-4), 45-456
4. IS 456-2000, (Fourth Revision). Plain and Reinforced concrete - Code of Practice. *Bureau of Indian Standards.*, New Delhi, India
5. IS 13920-1993, (Reaffirmed 1998). Ductile detailing of Reinforced Concrete Structures subjected to Seismic Forces Code of Practice. *Bureau of Indian Standards.*, New Delhi, India
6. Kumar V, Nautiyalil BD, Kumar S. A Study of Exterior Beam- Column Joints. *Indian Concrete Journal.*, 1991, 55(2), 39-43
7. Malathy R, Subramanian K, Rameshkumar M. Effect of Glass Fibre on Restrained Plastic Shrinkage Cracking of HPC with Silica Fume. *Journal of Scientific and Industrial Research.*, 2007, 66, 748-751
8. Murthy CVR, Rai DC, Bajpai KK, Jain SK. Effectiveness of Reinforced Details in Exterior Reinforced Concrete Beam-Column Joints for Earthquake Resistance. *ACI Structural Journal.*, 2008, 100, 49-155
9. Perumal P, Thanukumari B. Seismic Performance of Hybrid Fibre Reinforced Beam-Column Joint. *International Journal of Civil and Structural Engineering.*, 2010, 1(3), 749-774

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